From this it may be seen that at more than 9,000 feet the catch averaged less than one specimen to every three groups of buildings. Between 9,000 and 7,000 feet it averaged between one and two specimens per group of buildings—22 groups yielding 27 specimens. It is only at a distance of 7,000 feet or less that the numbers are great enough to be of definite importance.

Comparing this with the conclusions drawn provisionally from the experiments of Le Prince with stained mosquitoes it is seen that they are in relative agreement in indicating a flight of approximately 7,000 feet in numbers sufficient to be important. In practical antimalaria work, therefore, it would appear justifiable to control a zone approximately 7,000 feet wide around the area to be protected, increasing or decreasing the distance according to special local conditions.

This, of course, may not apply to species other than those studied. For instance, in the eastern United States *Anopheles punctipennis* may not conform to the range of flight of *quadrimaculatus* and *crucians*, although it probably does not deviate far from it.

With respect to the importance of *crucians* as an agent in malaria transmission there is little to add to what has already been said. Its habits would indicate that it is not so important as *quadrimaculatus*, although it may be more important than *punctipennis*. This question is being studied by the writer at the present time.

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## TREATMENT AND DISPOSAL OF CREAMERY WASTES.

By Earle B. Phelps, Professor of Chemistry, Hygienic Laboratory, United States Public Health Service.

An experimental investigation of the treatment and disposal of creamery wastes was carried out during the years 1916–17 by the United States Public Health Service, cooperating with the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture.[1] This investigation was carried out at the plant of the

[1] This investigation was in immediate charge of Sanitary Engineer H. B. Hommon, United States Public Health Service, who is responsible for its general plan and direction. He was assisted in the design and construction by Sanitary Engineer H. R. Crohurst and, during the period of operation, by Sanitary Chemist H. P. Corson, in resident charge. Mr. L. A. Rogers, Bacteriologist, in Charge of Research Laboratories, Dairy Division, cooperated throughout and lent helpful assistance. The work of preparation of a complete report was interrupted by the advent of the war, and Mr. Hommon is now serving in France as a captain in the Sanitary Corps, United States Army. This preliminary presentation of methods and results is made, because of a considerable demand for information upon the subject and in order to make the results of the investigation promptly available. It is intended to publish the complete report at some later date.

demonstration creamery of the Dairy Division at Grove City, Pa. It was begun in October, 1915, but owing to difficulties of construction and necessity for remodeling, the actual satisfactory operation of the plant was delayed until May, 1916. It was discontinued at the end of October, 1917.

This creamery is operated under the supervision of the Dairy Division of the Department of Agriculture, and the business consists mainly of butter making. Some cottage cheese and casein are made, and other experimental work is carried on by the Government, but the wastes treated consisted essentially of those from making butter. The milk is delivered by the farmers to the creamery, where it is separated, most of the skimmed milk going back to the farmers. No skimmed milk or buttermilk goes into the sewer; in fact, nothing goes into the sewer that contains any product in amounts that can be utilized as food for either man or animals.

The wastes that were treated consisted of those from washing cans, and cleaning and rinsing the churns, together with a small amount of milk, cream and buttermilk that was spilled on the floors. The water used for condensing and cooling purposes and all exhaust steam were discharged into a separate sewer direct to the creek and were not treated with the other wastes from the creamery.

The experimental disposal plant consisted of a septic tank, an Imhoff tank, and two sand filters. Difficulties were had with the Imhoff tank, owing to imperfect construction work and leakage, leading to a considerable odor about the plant, so that this tank was not actually used during the investigation.

In May, 1916, the plant was put in operation, the sand filter being operated at a nominal rate of 25,000 gallons per acre per day, and the septic tank on the basis of a 12-hour storage period. The results of the operation were excellent almost from the start. During July the nominal rate of filtration was gradually increased to approximately 70,000 gallons per acre per day, at about which point it was maintained throughout the investigation. With the advent of cold weather a noticeable reduction occurred in the degree of nitrification, and a somewhat less marked effect was shown by the relative stability and oxygen demand values. The degree of purification was always satisfactory for discharge into a comparatively small volume of diluting water in cold weather, and the spring of 1917 brought with it increased biological activity and resulting improvement in quality of the effluent.

A noticeable and quite unexpected result was the complete neutralization of the characteristic acidity of the settled wastes, the average values for 18 months being 226 parts per million of acidity in the settled waste and 356 parts per million of bicarbonate alkalinity in the filter effluent. As the sand used was clean quartz sand, this change can be explained only as the result of biological activity. The following tables, I and II, give the average analytical results, by

months, of the raw and settled waste and of the filter effluent, together with rates of operation:

TABLE I.—*Monthly averages of analyses of creamery waste, before and after treatment in a septic tank, showing removal of certain constituents.*

[Analytical values in parts per million.]

| Date. | Suspended solids. | | | Organic nitrogen. | | | Oxygen consumed. | | | Acidity. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Untreated waste. | Tank effluent. | Removed. | Untreated waste. | Tank effluent. | Removed. | Untreated waste. | Tank effluent. | Removed. | Untreated waste. | Tank effluent. |
| **1916.** | | | *P. ct.* | | | *P. ct.* | | | *P. ct.* | | |
| May | 552 | 237 | 57 | 182 | 106 | 42 | 2,195 | 1,402 | 36 | 120 | 634 |
| June | 333 | 230 | 31 | 132 | 115 | 13 | 1,082 | 429 | 60 | 131 | 466 |
| July | 290 | 249 | 14 | 76 | 55 | 28 | 599 | 232 | 61 | ........ | 191 |
| August | 460 | 276 | 40 | 76 | 57 | 25 | 630 | 236 | 63 | ........ | 166 |
| September | 538 | 329 | 39 | 98 | 44 | 55 | 879 | 315 | 64 | ........ | 239 |
| October | 562 | 278 | 51 | 58 | 35 | 40 | 487 | 182 | 63 | ........ | 40 |
| November | 833 | 271 | 67 | 106 | 46 | 57 | 767 | 201 | 74 | 236 | 244 |
| December | 577 | 325 | 43 | 84 | 41 | 51 | 717 | 216 | 70 | 132 | 143 |
| **1917.** | | | | | | | | | | | |
| January | 567 | 306 | 46 | 95 | 53 | 44 | 578 | 215 | 63 | 116 | 141 |
| February | 601 | 289 | 52 | 106 | 44 | 58 | 802 | 258 | 68 | ........ | 138 |
| March | 1,114 | 515 | 54 | 122 | 51 | 58 | 1,285 | 275 | 79 | 220 | 141 |
| April | 916 | 566 | 38 | 78 | 45 | 42 | 757 | 240 | 68 | 32 | 40 |
| May | 525 | 250 | 52 | 66 | 34 | 48 | 762 | 257 | 66 | ........ | 184 |
| June | 531 | 280 | 47 | 62 | 42 | 32 | 628 | 243 | 61 | 70 | 210 |
| July | 380 | 219 | 43 | 44 | 34 | 23 | 816 | 215 | 74 | 153 | 376 |
| August | 400 | 214 | 47 | 34 | 27 | 20 | 468 | 153 | 67 | 125 | 160 |
| September | 360 | 233 | 35 | 67 | 37 | 45 | 716 | 208 | 71 | 220 | 198 |
| October | 386 | 182 | 53 | 72 | 56 | 22 | 715 | 222 | 69 | 185 | 323 |
| Weighted, average. | 517 | 279 | 46 | 84 | 50 | 40 | 782 | 283 | 64 | 153 | 226 |

TABLE II.—*Monthly averages of analyses of creamery waste, after treatment in a septic tank and through a sand filter, showing removal of certain constituents.*

[Analytical values in parts per million.]

| Date. | Suspended solids. | | Organic nitrogen. | | Oxygen consumed. | | Nitrate. | Dissolved oxygen. | Alkalinity. | Relative stability. | Rate of filtration, g. a. d. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Filter effluent. | Removed.[1] | Filter effluent. | Removed.[1] | Filter effluent. | Removed.[1] | | | | | |
| **1916.** | | *P. ct.* | | *P. ct.* | | *P. ct.* | | | | | |
| May | 16 | 97.1 | 7.33 | 96.0 | 50.0 | 97.7 | 21.4 | 1.8 | 282 | 78 | 25,000 |
| June | 8 | 97.6 | 13.65 | 89.7 | 60.0 | 94.5 | 103.0 | 2.3 | 161 | 95 | 24,900 |
| July | 13 | 95.5 | 1.12 | 98.5 | 29.0 | 95.2 | 43.9 | 1.8 | 304 | 94 | 46,500 |
| August | 7 | 98.5 | 1.20 | 98.4 | 10.5 | 98.3 | 19.3 | 3.2 | 344 | 88 | 72,800 |
| September | 5 | 99.1 | .27 | 99.7 | 10.1 | 98.9 | 11.5 | 2.9 | 418 | 79 | 71,100 |
| October | 16 | 97.2 | .63 | 98.9 | 8.8 | 98.2 | 12.5 | 6.9 | 340 | 95 | 67,400 |
| November | 17 | 98.0 | 1.22 | 98.8 | 9.5 | 98.8 | 11.5 | 8.8 | 299 | 82 | 62,200 |
| December | 4 | 99.3 | 1.21 | 98.6 | 6.2 | 99.1 | 6.8 | 9.5 | 352 | 85 | 63,000 |
| **1917.** | | | | | | | | | | | |
| January | 15 | 97.3 | 1.62 | 98.3 | 11.6 | 98.0 | 4.4 | 8.5 | 382 | 55 | 74,900 |
| February | 29 | 95.2 | 2.56 | 97.5 | 17.8 | 97.8 | 2.3 | 9.4 | 370 | 30 | 56,200 |
| March | 33 | 97.0 | 3.52 | 97.1 | 23.2 | 98.2 | 1.8 | 7.7 | 338 | 32 | 62,000 |
| April | 52 | 94.3 | 3.20 | 95.9 | 35.0 | 95.4 | ........ | 6.8 | 439 | 27 | 62,800 |
| May | 28 | 94.7 | 4.42 | 93.3 | 28.7 | 96.2 | 8.1 | 4.5 | 377 | 59 | 72,900 |
| June | 20 | 96.2 | 4.62 | 92.5 | 13.1 | 97.9 | 22.1 | 2.7 | 422 | 83 | ........ |
| July | 32 | 91.6 | 2.38 | 94.6 | 13.6 | 98.3 | 7.5 | 2.0 | 340 | 68 | 64,400 |
| August | 22 | 94.5 | 1.05 | 96.9 | 6.4 | 98.6 | 15.5 | 4.1 | 392 | 92 | 75,100 |
| September | 38 | 89.5 | 1.29 | 98.1 | 7.9 | 98.9 | 7.0 | 5.2 | 368 | 84 | ........ |
| October | 69 | 82.1 | 1.98 | 97.2 | 8.4 | 98.8 | 2.7 | 5.1 | 395 | 43 | ........ |
| Weighted, average. | 20 | 96.1 | 2.47 | 97.1 | 17.6 | 97.7 | 15.9 | 4.4 | 356 | 71 | ........ |

[1] Based on untreated waste.

The results of this investigation indicate the entire feasibility of satisfactorily treating creamery wastes. The investigation has been in no sense exhaustive, and, in particular, the advantages of Imhoff tank treatment in place of plain sedimentation have not been investigated. It has been demonstrated, however, that plain sedimentation is a satisfactory tank treatment preliminary to sand filtration, and, that with the following specifications, a disposal plant may readily be designed for satisfactory treatment of creamery wastes.

The settling tank should have a net capacity of about one day's output of the creamery. It should have one or more hopper bottoms with side slopes of 45 degrees and a sludge outlet pipe running nearly to the bottom. The total depth from water line to sludge outlet should be about 12 feet. There should be a vertical bottom baffle, extending 3 feet above the upper edge between each two hoppers, and scum baffles extending 5 feet into the liquid over the center of each hopper. The entire tank should be covered with a tight board cover. The effluent from the tank should overflow to a siphon chamber having a capacity of not less than one nor more than six hours' output of waste. This chamber should be provided with an automatic siphon discharging to the filter beds. (See fig. 1.)

The sand filters should have an area of about 725 square feet per 1,000 gallons daily output of waste. This is equivalent to 60,000 gallons per acre per day. The upper layer should be composed of 3 feet of clean fairly coarse sand, such as would be suitable for concrete. This sand should be laid upon an underdrain system composed of parallel or radiating lines of agricultural drain tile suitably imbedded in coarse stone graded upward to fine stone and gravel to exclude the upper sand layer. This filter should be divided into not less than 2 and preferably 4 units, with suitable arrangement for diverting the flow to one or another. The units should be used in rotation.

Intelligent supervision over the operation of this plant is essential. There will be required, first, the daily attention to alternating the doses. At periods varying from one week to one month in intervals, the filter surface may require a light raking. Semiannually the tank will require attention. The accumulated sludge must be removed from the bottom and scum from the surface. This material may be buried. In northern climates the filters will require annual preparation for winter. To this end they should be cleaned by lightly removing a surface layer of not over 1 inch, and then worked into furrows running radially from the point of application of the dose. The ridges of these furrows should project just above the water line when the full dose is applied. During cold weather they support the accumulated ice layer and permit the continued operation of the filter.

Figure 1 is a perspective view of the settling tank, showing all essential details. It is designed for a daily output of wastes of 5,000

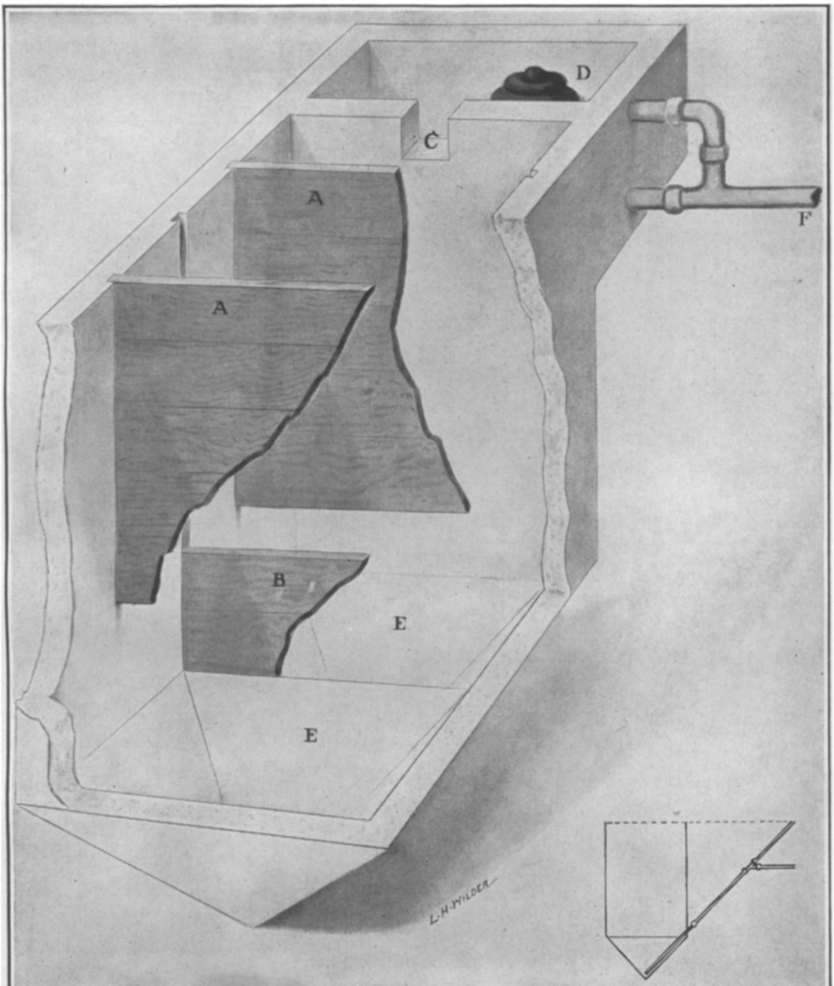


Fig. 1.—Diagrammatic view of septic tank.

gallons. The inside dimensions of the main body of the tank are 7 feet by 14 feet. The rectangular section is 10 feet deep and the hoppers, E, are 3½ feet deep. Baffles A–A extend 5 feet below the water line, and baffle B, 3 feet above the concrete ridge. The outlet C is 1 foot square. The siphon tank D has inside dimensions of 3 feet by 7 feet and 4 feet deep. The sludge-removal pipes, one in each hopper, are not shown on the main sketch, but their location and connections are indicated in the small sketch below.

The sludge line from each hopper should be made of 6-inch pipe, with valves on each line located outside the tank at such an elevation that there will be at least 3 feet static head over the outlet, when the tank is full of waste, to remove the sludge. It will probably not be necessary to remove the sludge more than once a year or possibly once in two years. As a rule the sludge will not be offensive and can be run out on a well-drained piece of ground near the plant and left to dry. It can then be removed and buried or used on land as a fertilizer. If the plant is located near dwellings it may be advisable to dig shallow trenches and cover the sludge with earth as soon as drawn. If the plant is not too near the creamery or private dwellings, a bed of cinders with a fine layer of sand on the surface makes a more satisfactory drying bed. This bed should be 12 inches deep and underdrained with tile, but without the coarse material used in the sand filters. On such a bed the sludge can be dried in about 15 days of clear weather. It is generally advisable to draw the sludge off in the fall after the flies are dead, or early spring before they appear, and it should be done when the creek that receives the wastes is in flood so that the drainage, which will be small, can go direct to the creek.

There are two ways of removing the scum. One is to churn it up and cause as much as possible to settle to the bottom and draw it off with the sludge, and the other is to draw it off with buckets. The scum removed can be hauled away in a water-tight wagon, or it can be placed in shallow piles near the plant and covered with a thin layer of earth. The latter method is preferable and is the one recommended.

The instructions given here are sufficient to enable a sanitary engineer to construct this plant properly. It is not possible to set down more detailed specifications, except with full knowledge of the exact data of the plant in question. It is essential, however, that the works be properly designed to meet the specific requirements, and the services of a competent engineer in designing and constructing this plant are distinctly desirable.

While it is probable that with careful operation the plant described will not give rise to objectionable odors, the possibility of nuisance can not be entirely overlooked, especially during the first few months

of operation. For this reason it is desirable wherever practicable to locate the plant at some distance from dwellings and from the creamery, and to cover the tank with a tight board cover. This cover will also tend to prevent serious fly nuisance.

In view of the rather common use of septic tanks in connection with the disposal of creamery wastes, it ought to be emphasized that the septic tank itself does not constitute a system of final treatment. While such a tank provides considerable removal of organic material, the comparative figures of Table I show that in the essential constituents, particularly the total organic nitrogen and the oxygen consumed, there has not been sufficient improvement to prevent nuisance under the usual conditions of discharge. The primary function of a septic tank is to prepare the waste for further oxidation, and the use of the sand filter for this purpose makes it possible to discharge a final waste which is practically unobjectionable.